

## A Further Study on Short Term Memory Improvement by Neurofeedback

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**Abstract**—Our previous study successfully improved short term memory by individual alpha neurofeedback training. However, short term memory and its improvement in different languages are still not clear. Therefore, the purpose of this paper was to evaluate the memory performance in alphabetic and ideographic language groups. Besides, the relationship between initial memory and its improvement was investigated. The results indicated short term memory in ideographic language was higher than those in alphabetic language and forward digit span improvement was positive related to its initial performance.

**Keywords**- neurofeedback; individual alpha frequency; short term memory; digit span

### I. INTRODUCTION

The property of short term memory is the limited capacity. Previous study on short term memory reported that human can store approximately  $7 \pm 2$  items [1]. One interesting point is raised by the influence of mother or first language on short term memory and its improvement. For example, Chinese has many thousands of characters, each of which represents one syllable morphemes. These characters have only a loose orthographic-phonemic correspondence and their pronunciation is acquired via rote associative learning [2]. While many alphabetic languages have about thirty symbols, for instance, English has an alphabet of 26 symbols. According to the identity of an ideographic language, Chinese characters are hard to write, read and remember. For English, it is needed to remember 26 symbols and as an alphabetic language feature, most of the words could be written as their pronunciation.

Although some studies compared the short term memory performance between different linguistic languages [3], [4], however, the difference in its improvement between different languages is still unknown. To this end, the first step is to improve memory performance by neurofeedback (NF). NF is an effective tool on the improvement of peak performance [5] as well as treatment for psychiatric disorders [6]. During NF, electroencephalogram (EEG) is recorded from one or more electrodes placed on the scalp and the relevant components are extracted and fed back to the individuals online in the form of visual, audio or combined audio-visual information [5].

Recent findings suggest that memory performance is related to EEG alpha activity. The increased resting power but small “test” power during memory task in alpha band is associated with good memory performance [7]. Therefore,

our previous study utilized individual alpha NF training to improve short term memory [8].

Based on the results in [8], the purpose of this paper was to compare short term memory performance between alphabetic and ideographic language groups. Meanwhile, the relationship between initial memory performance and its ability of improvement under the same NF condition was investigated.

### II. METHODS

#### A. Participants

Fifteen students (eleven males and four females, aged 20-27 years: mean=23.07, SD=2.11) took part in the NF training. Among them, five students (from Europe) were in alphabetic language group and ten students were in ideographic language group (native speakers of Mandarin Chinese). Informed written consent was obtained from all participants before the experiment. The protocol was approved by the Research Ethics Committee (University of Macau).

#### B. EEG Recordings

EEG was recorded on channel Cz of the “10-20 International System of Electrode Placement” with sampling frequency 256 Hz, the reference was the average of both mastoids and the ground was located at forehead. The signals were amplified by a 24-channel system (Vertex 823 from Meditron Eletromedicina Ltda, SP, Brazil) and were recorded by Somnium software platform (Cognitron, SP, Brazil). The impedance was kept below  $10k\Omega$  for all electrodes.

#### C. Experimental Procedure

At first, two EEG epochs of 60 seconds each during the resting period were recorded while the participants had their eyes opened and closed respectively. The recordings of eyes opened and closed provided data for the determination of IAF band. After the baseline recordings, all participants completed digit span test which consisted of forward and backward digit span to measure short term memory (as pretest). Each digit span test consisted of a series of trials showing random digits at the rate of one digit per second. At each trial the number of digits shown was increased by one until the participant failed twice to recollect every digit. The last number of digits correctly recollect was the participant’s digit span. In each test, after all the digits had been shown, the participant was instructed to input the digits with the same order (forward digit span) or with the inverse

order (backward digit span) as they were displayed. After 20 training sessions, the digit span tests were performed again (as posttest).

NF training was administered 3 to 4 sessions per day for a total of 20 sessions. The participants can perform any kind of mental strategy to achieve the successful training. For the first two sessions, participants can control the number and the length of trials for better familiarization with the NF display and mechanism. At the end of each trial, they can input a comment on cognitive strategies they had used in the training. The comments were used to find out more effective cognitive strategies for the desired changes. For the remaining 18 sessions, the number and the length of the trials were fixed and the participants were expected to apply the most successful cognitive strategies and try their best to achieve the desired changes within the time limit. Each fixed session was composed of 10 successive trials of 20 seconds each and with an interval of 5 seconds between trials. The details of feedback principle and display are described in [8].

### III. RESULTS

#### A. The Comparison of Memory between Alphabetic and Ideographic Language Groups

Fig. 1 shows the average digit span results for both groups. As depicted in Fig. 1, digits were improved in both groups after training. More specifically, ideographic group increased 43.02% in forward digits and 45.57% in backward digits, while alphabetic group increased 35.29% in forward digits and 40.63% in backward digits. The average result in ideographic group was higher than that in alphabetic group for both pretests and posttests.

Table I presents the maximum and minimum digit span results at pre and post tests for both groups. As shown in Table I, all parameters in ideographic group were higher than those in alphabetic group.

Digit span results for alphabetic and ideographic language groups

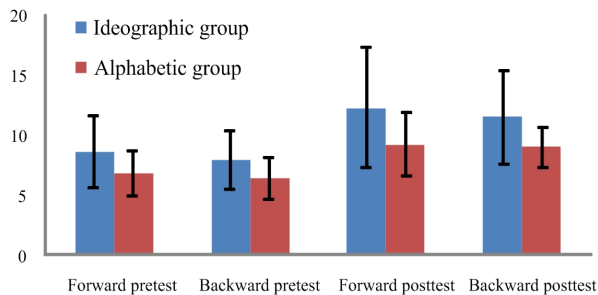


Figure 1. The average digit span results for two groups, the error bar presents the standard deviation of each test.

TABLE I. MAXIMUM AND MINIMUM DIGITS FOR BOTH GROUPS

Digits	Alphabetic group		Ideographic group	
	Forward	Backward	Forward	Backward
Pretest maximum	10	9	17	13
Posttest maximum	14	11	26	22
Pretest minimum	5	4	6	5
Posttest minimum	7	6	8	9

#### B. The Relationship between Ability of Memory Improvement and Initial Memory Performance.

The global forward and backward digit span were increased after 20 NF sessions. The details are described in [8]. Here, we only focus on the correlation between initial memory performance before NF training and the ability of memory enhancement. As shown in Fig. 2, the forward digit test has a linear lower bound for improvement, the minimal increase was 1 from pretest digit span of 7 and it increased linearly. While this linear relation is not found in backward digit test. Pearson correlation coefficient was 0.8 for forward tests, and this correlation was significant ( $p < 0.001$ ). For backward digit span, the Pearson correlation coefficient was 0.377 and there was no significant correlation between increased digits and pretest ( $p > 0.05$ ).

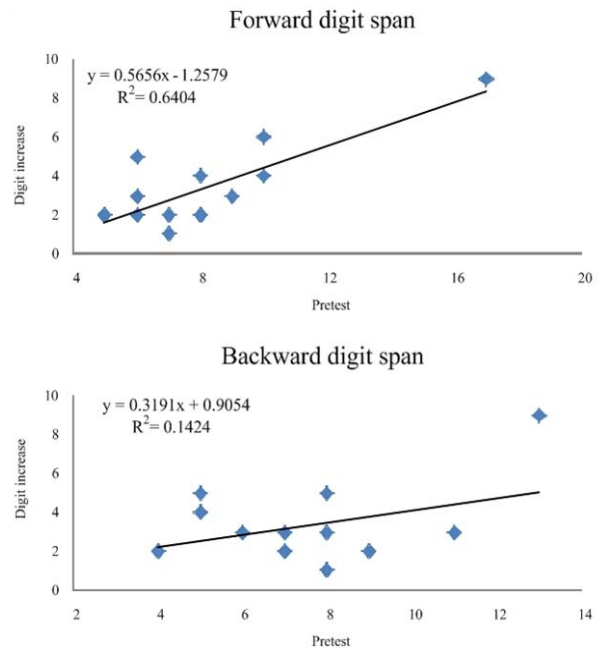


Figure 2. The relationship between digit increase and pretest. The upper part is for forward digit span and the lower part is for backward digit span

#### IV. DISCUSSION

This paper extended our previous work on short term memory performance improvement by individual alpha NF in healthy individuals.

The comparison of memory performance between ideographic and alphabetic language groups shows that the subjects in ideographic group have higher memory performance at pre and posttest. One possible reason is that Chinese schools have more repetitive practice than European classrooms. Furthermore, another important reason is the differences in pronunciation duration between different languages, digits in ideographic language require much shorter pronunciation duration than those in alphabetic language. These differences could be due to inherent differences in the linguistic structure of the words themselves [4].

Under the same NF training condition, the increase in forward digit span is positive related to the initial memory performance, while the increase in backward digit span does not show significant correlation with initial backward memory performance.

#### V. CONCLUSION

In conclusion, this paper shows ideographic group has higher memory performance than alphabetic group and the increase in forward digit span under the same NF condition is positive related to initial memory performance, which shows a linear lower bound for forward digit span. Due to the limited number of subjects, further study is needed to confirm this finding.

#### ACKNOWLEDGMENT

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